4.7 External Radiation Surveillance

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External radiation is defined as radiation originating from a source outside the body. External radiation fields consist of a natural component and an artificial or manmade component. The natural component can be divided into 1) cosmic radiation; 2) primordial radionuclides in the earth's crust (primarily potassium-40, thorium-232, and uranium-238); and 3) an airborne component, primarily radon and its progeny. The manmade component consists of radionuclides generated for or from nuclear medicine, power, research, waste management, and consumer products containing nuclear materials. Environmental radiation fields may be influenced by the presence of radionuclides deposited as fallout from atmospheric testing of nuclear weapons or those produced and released to the environment during the production or use of nuclear fuel. During any year, external radiation levels can vary from 15% to 25% at any location because of changes in soil moisture and snow cover (National Council on Radiation Protection 1987).

The interaction of radiation with matter results in energy being deposited in matter. This is why your hand feels warm when exposed to a light source (e.g., flame, light bulb, sun, etc.). Ionizing radiation energy deposited in a mass of material is called radiation absorbed dose. A special unit of measurement, called the rad, was introduced for this concept in the early 1950s, and more recently, an International System (SI) unit called the gray (Gy) has been defined: 1 Gy is equivalent to 100 rad (American Society for Testing and Materials 1993).

One device for measuring radiation absorbed dose is the thermoluminescent dosimeter. Thermoluminescence, or light output exhibited by thermoluminescent dosimeters, is proportional to the amount of radiation exposure (X), which is measured in units of roentgen (R). The exposure is multiplied by a factor of 0.98 to convert to a dose (D) in rad to soft tissue (U.S. Department of Health, Education and Welfare 1970). This conversion factor relating R to rad is, however, assumed to be unity (1) throughout this report for consistency with past reports. This dose is further modified by a quality factor, Q = 1 for beta and gamma radiation, and the product of all other modifying factors (N). N is assumed to be 1 to obtain dose equivalence (H), measured in rem. The seivert (Sv) is the SI equivalent of the rem.

$$D\ (\text{rad}) \approx X\ (\text{R}) * 1.0$$
$$H\ (\text{rem}) \approx D * N * Q$$

To convert to SI units of grey and sievert, divide rad and rem by 100, respectively.

Environmental external radiation exposure rates were measured at locations on and off the Hanford Site using thermoluminescent dosimeters. External radiation and surface contamination surveys at these locations were also performed with portable radiation survey instruments at locations on and around Hanford. This section describes how external radiation was measured, how surveys were performed, and gives the results of these measurements and surveys.

External Radiation Measurements

In 1995, a new Harshaw 8800 series system replaced the old Hanford standard environmental dosimeter system. The Harshaw dosimeter consists of two TLD-700 and two TLD-200 chips. This dosimeter provides both shallow- and deep-dose measurement capabilities. Thermoluminescent dosimeters are positioned approximately 1 m (3.3 ft) above the ground at 24 locations onsite (Figure 4.7.1), four around the site perimeter, in eight nearby and two distant communities (Figure 4.7.2), and 28 locations along the Hanford Reach of the Columbia River (Figure 4.7.3). The thermoluminescent dosimeters are collected and read quarterly. The two TLD-700 chips at each location are used to determine the average total environmental dose at that location. The average dose rate is computed by dividing the average total environmental dose by the length of time the thermoluminescent dosimeter was in the field. Quarterly dose equivalent rates (mrem/d) at each location were converted to annual

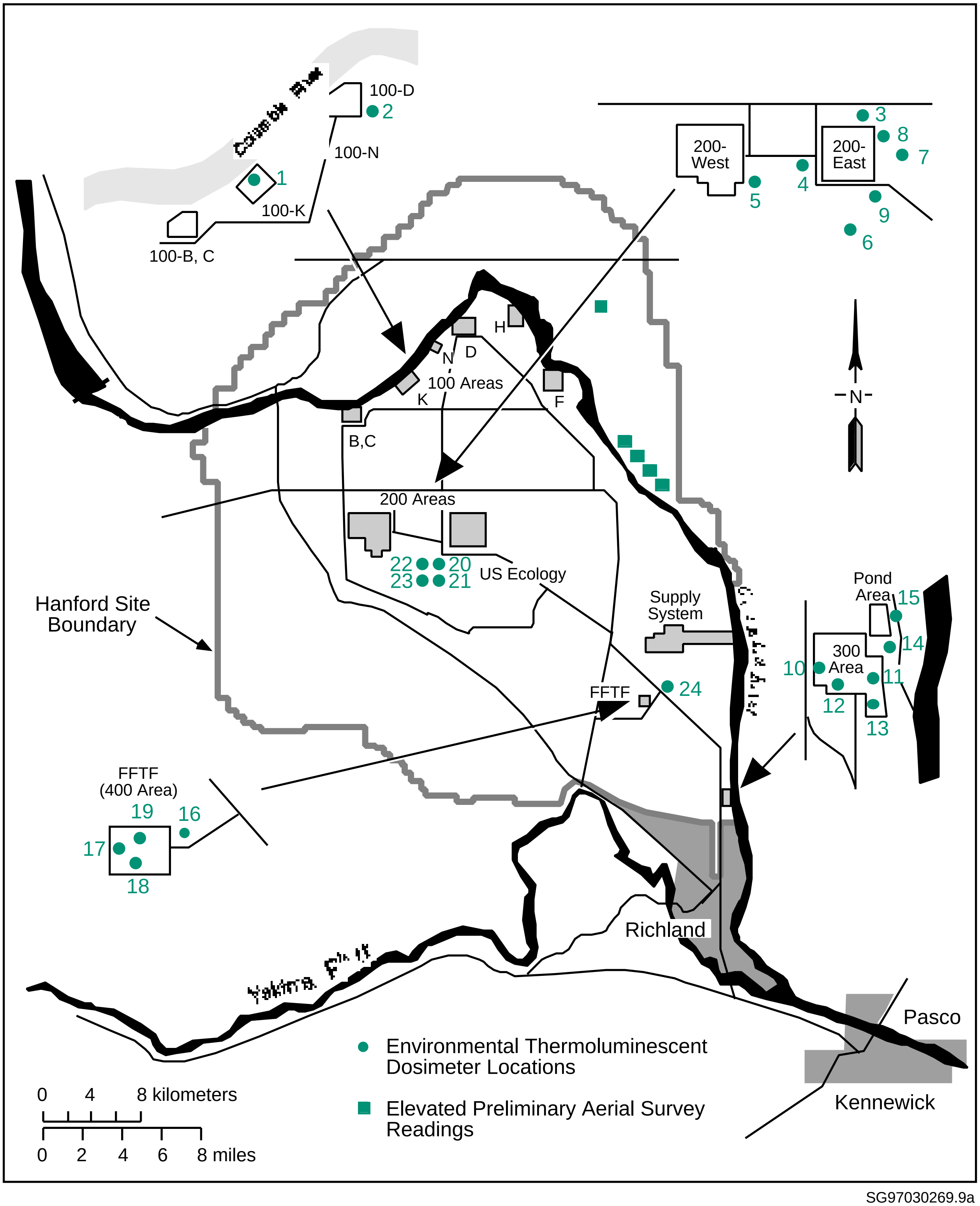

Figure 4.7.1. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Site, 1996

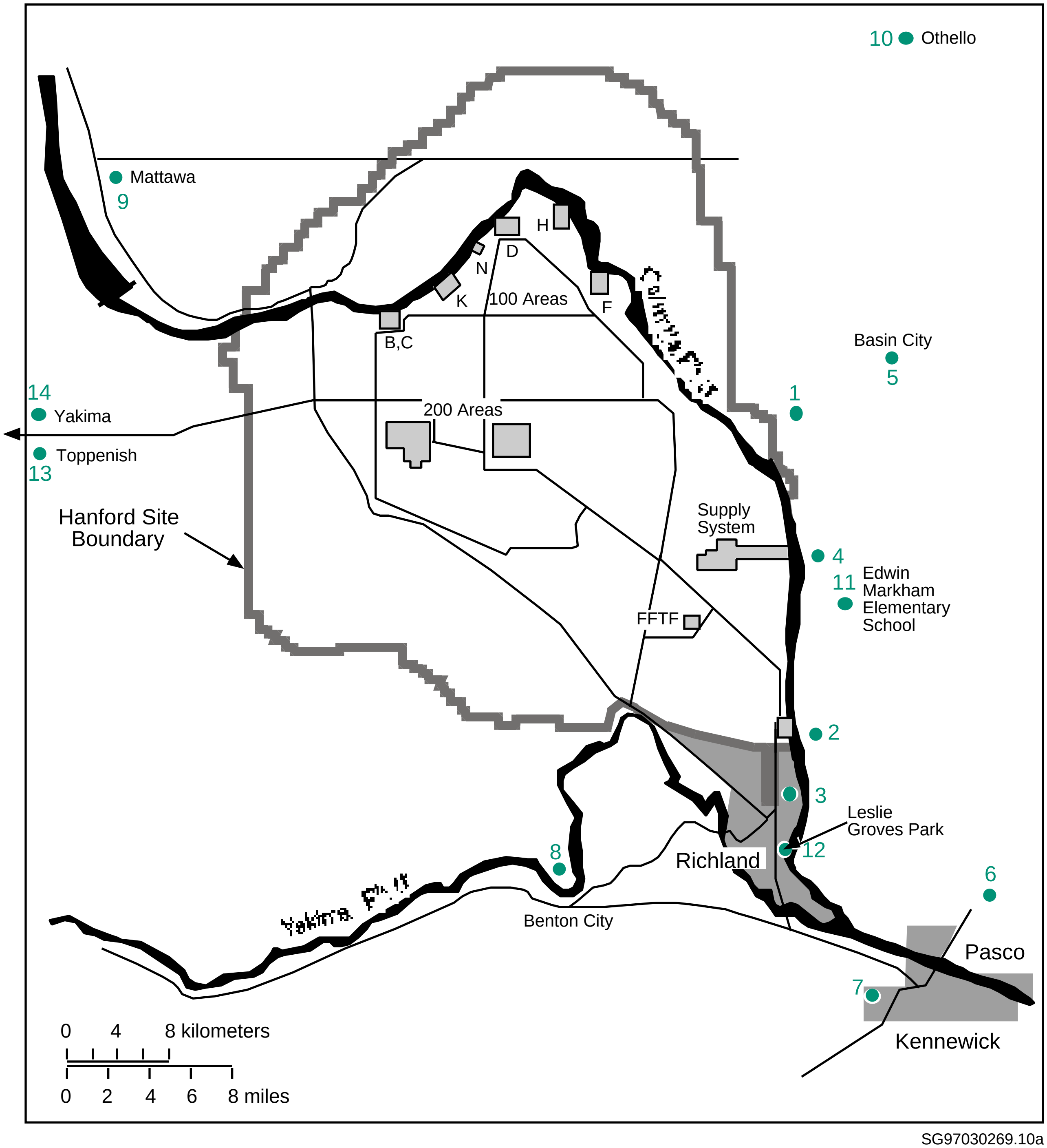

Figure 4.7.2. Thermoluminescent Dosimeter Locations and Station Numbers for Community, Distant, and Perimeter Sites, 1996

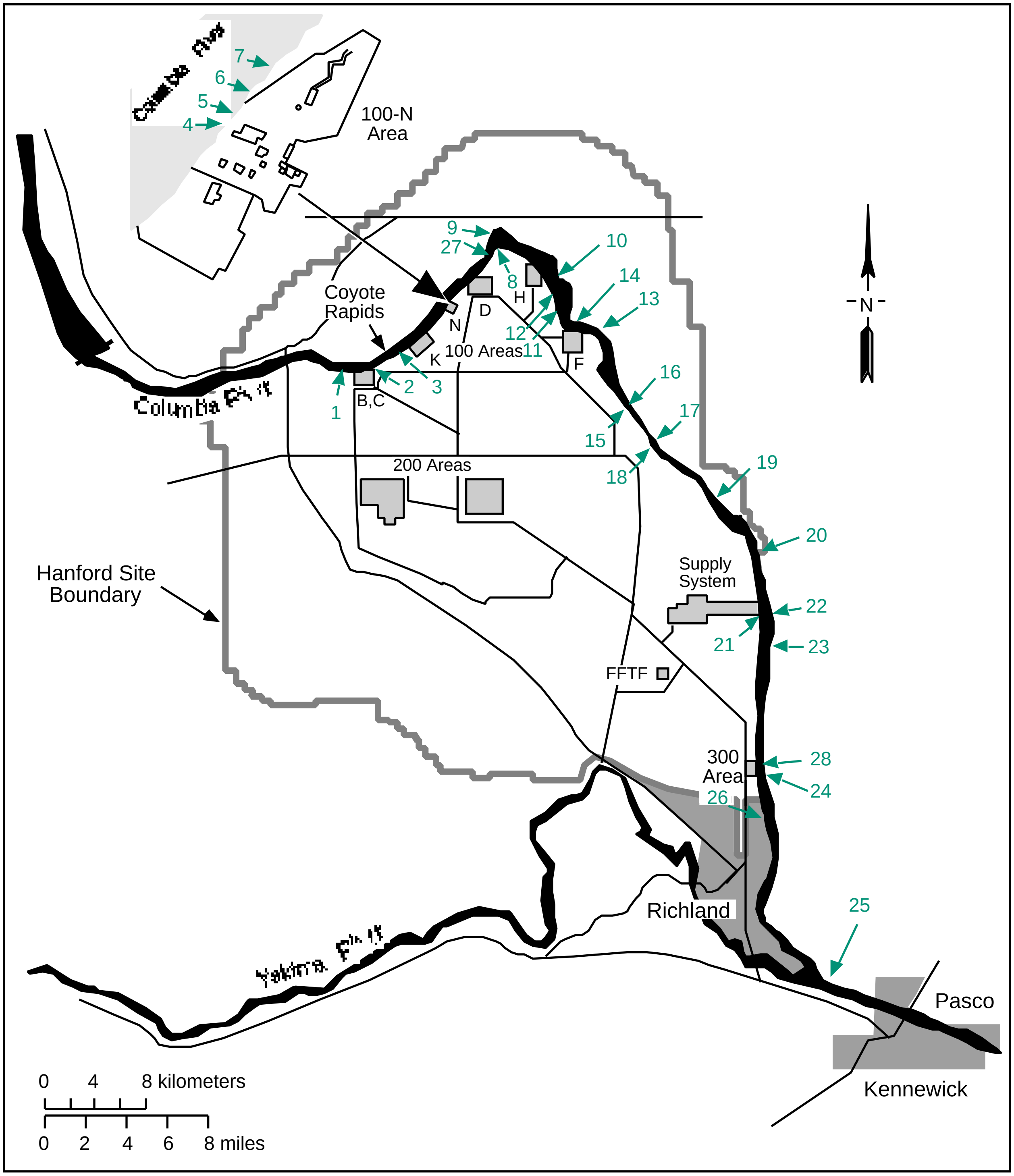

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Figure 4.7.3. Thermoluminescent Dosimeter Locations and Station Numbers on the Hanford Reach of the Columbia River, 1996

dose equivalent rates (mrem/yr) by averaging the quarterly dose rates and multiplying by 365 d/yr. The two TLD-200 chips are included to determine doses in the event of a radiological emergency.

All community and most of the onsite and perimeter locations are collocated with air monitoring stations. The onsite and perimeter locations were selected based on historical determinations of the highest potentials for public exposures (access areas, downwind population centers) from past and current Hanford operations. The two background stations in Yakima and Toppenish were chosen because they are generally upwind and distant from the site.

Twenty-eight thermoluminescent dosimeter locations are established along the Columbia River shoreline (see Figure 4.7.3), from upstream of the 100-B Area to just downstream of Bateman Island at the mouth of the Yakima River. The general public has access to most of this shoreline.

External Radiation Results

Thermoluminescent dosimeter exposures have been converted to dose equivalent rates by the process described above. Table 4.7.1 shows maximum and mean dose rates for perimeter and offsite locations measured in 1996 and the previous 5 years. External dose rates reported in Tables 4.7.1 through 4.7.3 include the maximum annual average dose rate (±2 standard error of the mean) for all locations within a given location classification and the mean dose rate (±2 standard error of the mean) for each class. The mean dose rates were computed by averaging the annual means for each location within a location classification. Locations were classified (or grouped) based on their distance from the site.

In 1996, the annual average perimeter external radiation dose rate was 88 ± 10 mrem/yr (see Table 4.7.1), while in 1995, the average was 86 ± 8 mrem/yr. The mean background external radiation dose rate (in distant communities in 1996) was 71 ± 1 mrem/yr, compared to the 1995 perimeter average of 72 ± 8 mrem/yr (Dirkes and Hanf 1996) and a 5-year perimeter average of 99 ± 4 mrem. Simple, two-tailed t-tests were unable to show a significant difference between 1995 and 1996 data, $p = 0.52$ and $p = 0.89$, respectively. The small variation in exposure rates may be partially attributed to changes in natural background radiation that can occur as a result of changes in annual cosmic radiation (up to 10%) and terrestrial radiation (15% to 25% [National Council on Radiation Protection 1987]). Other factors possibly affecting the annual dose rates reported here may include variations in the sensitivity of individual thermoluminescent dosimeter zero-dose readings, fading, random errors in the readout equipment, procedural errors (Rathbun 1989), and changes in station locations. These changes include, but are not limited to, the discontinuation of thermoluminescent dosimeter locations or the changing of a location to avoid continual vandalism. Figure 4.7.4 graphically displays a comparison between, and trends

Table 4.7.1. Dose Rates Measured by Thermoluminescent Dosimeters at Perimeter and Offsite Locations, 1996 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[(a)]				
		1996		1991-1995		
Location	Map Location[(b)]	Maximum[(c)]	Mean[(d)]	No. of Samples	Maximum[(c)]	Mean[(d)]
Perimeter	1 - 4	97 ± 5	88 ± 10	27	121 ± 17	99 ± 4
Community	5 - 12	89 ± 3	79 ± 3	40	106 ± 16	89 ± 3
Distant	13 - 14	72 ± 3	71 ± 1	12	100 ± 11	85 ± 6

(a) ±2 standard error of the mean.
(b) All station locations are shown in Figure 4.7.2.
(c) Maximum annual average dose rate (±2 standard error of the mean) for all stations within a given location.
(d) Means ±2 standard error of the mean computed by averaging annual means for each station within each location.

Table 4.7.2. Dose Rates Measured by Thermoluminescent Dosimeters Along the Hanford Reach of the Columbia River, 1996 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1996		1991-1995		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
Typical shoreline	1 - 24	95 ± 3	82 ± 3	118	167 ± 159	106 ± 3
100-N Shoreline[e]	25 - 28	173 ± 5	129 ± 30	19	355 ± 143	221 ± 27
All shoreline	1 - 28	173 ± 5	89 ± 7	137	355 ± 143	123 ± 8

(a) Quarterly integrated readings in mR/d were converted to annual dose equivalent rates (mrem/yr).
(b) All locations are shown in Figure 4.7.3.
(c) Maximum annual average does rate (±2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed by averaging annual means for each location within the area.
(e) Monthly integrated exposure readings in mR/d converted to annual dose equivalent rates in mrem/yr.

Table 4.7.3. Dose Rates Measured by Thermoluminescent Dosimeters on the Hanford Site, 1996 Compared to Values from the Previous 5 Years

		Dose Rate, mrem/yr[a]				
		1996		1991-1995		
Location	Map Location[b]	Maximum[c]	Mean[d]	No. of Samples	Maximum[c]	Mean[d]
100 Areas	1 - 2	88 ± 5	80 ± 16	14	115 ± 21[e]	96 ± 7
200 Areas	3 - 9	92 ± 1	86 ± 4	39	121 ± 10	98 ± 3
300 Area	10 - 15	85 ± 4	81 ± 2	30	110 ± 18	94 ± 3
400 Area	16 - 19	85 ± 2	82 ± 2	20	111 ± 18	96 ± 4
600 Area	20 - 25	138 ± 5	97 ± 21	30	183 ± 16	109 ± 10
Combined Onsite	1 - 25	138 ± 5	86 ± 5	134	183 ± 16	100 ± 3

(a) Quarterly integrated readings in mrem were converted to annual dose equivalent rates.
(b) Locations are identified in Figure 4.7.1.
(c) Maximum annual average dose rate (±2 standard error of the mean) for all locations within a given area.
(d) Means ±2 standard error of the mean computed using pooled quarterly data.
(e) Only one quarter of data for this maximum; error term is two times the analytical counting error.

of, onsite, perimeter, and distant thermoluminescent dosimeter locations during 1991 through 1996.

Locations of the thermoluminescent dosimeters positioned along the Columbia River shoreline were shown in Figure 4.7.3, and Table 4.7.2 showed the measured dose rates for shoreline locations. Dose rates were highest near the 100-N Area shoreline, approximately 1.5 times the typical shoreline dose rates. The high rates measured in the 100-N Area historically have been attributed to past waste management practices in that area (Sula 1980). The maximum reading from the 100-N Area shoreline was 176 mrem/yr for both the third and fourth quarters at the station located at the 100-N Area springs. The general public does not have legal access to the 100-N Area shoreline but does have access to the adjacent Columbia

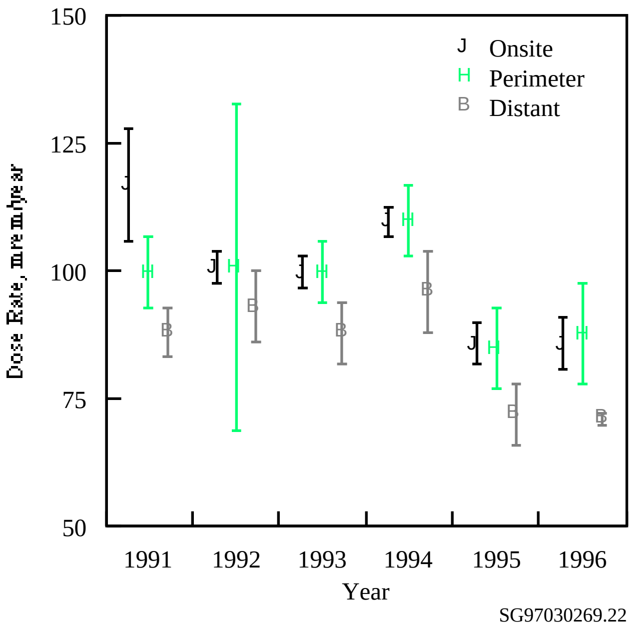

Figure 4.7.4. Annual Average Dose Rates (±2 standard error of the mean), 1991 Through 1996

River. The dose implications associated with this access are discussed in Section 5.0, "Potential Radiation Doses from 1996 Hanford Operations."

Table 4.7.3 summarized the results of 1996 measurements, which are grouped by operational area. The average dose rates in all operational areas were higher than average dose rates measured at background locations. The highest average dose rate onsite was seen in the 600 Area and was due to waste disposal activities at US Ecology Inc., a non-DOE facility.

Radiation Survey Results

In 1996, hand-held survey instruments were used to perform radiation surveys at selected Columbia River shoreline thermoluminescent dosimeter locations. These surveys provided a coarse screening for elevated radiation fields. The surveys showed that radiation levels were comparable to levels observed at the same locations in previous years. The highest levels were seen along the Columbia River shoreline in the 100-N Area and ranged from 8 to 20 µrem/h. As a point of comparison, 20 µrem/h equates to 175 mrem/yr, which correlates well with the maximum quarterly dose rate measured by the thermoluminescent dosimeters. Survey information is not included in the 1996 data volume (Bisping 1997), but is maintained in the Surface Environmental Surveillance Project files at Pacific Northwest National Laboratory and can be provided on written request.

Franklin County Elevated Gamma Measurements

EG&G Energy Measurements, Inc. performed an aerial radiological survey of the Hanford Site in March 1996. Preliminary results of this survey indicated elevated (up to 10 µR/h above background) exposure levels in Franklin County across the Columbia River from the Old Hanford Townsite. The elevated exposure levels were tentatively attributed to europium and cobalt isotopes. These preliminary data were of interest because elevated radiation levels had not been identified at these locations in previous aerial surveys (EG&G Energy Measurements, Inc. 1975, 1982, 1990). Five locations across the Columbia River, north of Ringold, were identified as having elevated exposure rates (see Figure 4.7.1).

A qualitative evaluation of radionuclides present at each of these locations was conducted with a portable gamma spectrometer. At each location, the primary radionuclides contributing to the exposure levels were associated with the natural uranium-238 or thorium-232 decay series. Other radionuclides not in the above-mentioned decay series but also identified in each spectra collected and, hence, contributing to the exposure rates were potassium-40, also a natural radionuclide, and cesium-137, a radionuclide present in worldwide fallout.

Radionuclides contributing to the elevated exposure rates noted in the aerial survey have been identified as naturally occurring gamma emitters in the thorium-232 or uranium-238 decay series, potassium-40 and cesium-137. The tentative identification of europium and cobalt was in error. This conclusion is in agreement with previous investigations by Rathbun (1989).

Gamma Radiation Measurements

During 1996, gamma radiation levels in air were continuously monitored at four community-operated air monitoring stations (Section 6.4, "Community-Operated Environmental Surveillance Program"). These stations were located in Leslie Groves Park in Richland, at Edwin Markham Elementary School in north Franklin County, at Basin City Elementary School in Basin City, and at

Heritage College in Toppenish (see Figure 4.1.1). Measurements were collected to determine ambient gamma radiation levels near and downwind of the site and upwind and distant from the site, to display real-time exposure rate information to the public living near the station, and to be an educational aid for the teachers who manage the stations.

Measurements at the Basin City and Edwin Markham schools were obtained using Reuter-Stokes Model S-1001-EM19 pressurized ionization chambers connected to Reuter-Stokes RSS-112 Radiation Monitoring Systems. Data were collected every 5 seconds, and an average reading was calculated and recorded on an electronic data card every 30 minutes. Data cards were exchanged monthly. Readings at the Leslie Groves Park and Heritage College stations were collected every 10 seconds with a Reuter-Stokes Model RSS-121 pressurized ionization chamber, and an average reading was recorded every hour by a flat panel computer system located at the station. Data were obtained monthly from the computer via modem. Data were not collected at every station every month because of problems with recording instruments and electrical service. The number of data collected at each station each month are provided in Table 4.7.4.

Table 4.7.4. Average Exposure Rates Measured by Pressurized Ionization Chambers at Four Offsite Locations

	Average Exposure Rate, μR/h[(a)](number of readings)[(b)]			
Sampling Locations[(c)]	Leslie Groves Park[(d)]	Basin City[(e)]	Edwin Markham[(e)]	Heritage College[(d)]
Month				
January	8.7 ± 0.5 (745)	8.3 ± 0.6 (1,414)	8.7 ± 0.8 (1,360)	[(f)]
February	8.6 ± 0.5 (557)	8.3 ± 0.4 (1,233)	8.6 ± 0.6 (1,441)	[(f)]
March	ND[(g)]	8.4 ± 0.4 (1,452)	8.7 ± 0.5 (1,344)	[(f)]
April	ND	8.3 ± 0.3 (1,589)	9.4 ± 40.1 (1,822)	[(f)]
May	8.4 ± 0.3 (719)	8.2 ± 0.2 (1,439)	ND	7.8 ± 0.2 (623)
June	8.3 ± 0.4 (718)	8.2 ± 0.3 (1,336)	ND	7.8 ± 0.2 (394)
July	8.3 ± 0.4 (573)	8.2 ± 0.3 (1,419)	ND	7.8 ± 0.3 (467)
August	8.3 ± 0.5 (741)	8.2 ± 0.3 (1,567)	ND	ND
September	8.4 ± 0.4 (720)	8.2 ± 0.3 (1,440)	ND	7.9 ± 0.4 (664)
October	8.6 ± 0.5 (547)	ND	ND	ND
November	8.7 ± 0.6 (588)	ND	ND	7.8 ± 1.1 (698)
December	8.6 ± 0.6 (550)	8.1 ± 1.0 (1,273)	8.7 ± 1.0 (912)	7.2 ± 0.7 (744)

(a) Averages are ±2 times the standard error of the mean.
(b) Number of 30- or 60-minute averages used to compute monthly average.
(c) Sampling locations are illustrated in Figure 4.1.1.
(d) Readings are stored every 60 minutes. Each 60-minute reading is an average of 360 individual measurements.
(e) Readings are stored every 30 minutes. Each 30-minute reading is an average of 360 individual measurements.
(f) Station under construction, not yet operational.
(g) ND = No data collected; equipment or power problems.

The measurements recorded at Basin City, Edwin Markham, and Leslie Groves Park during the year were similar and at background levels. Data collected at Edwin Markham during the first half of April included some variable readings associated with an equipment problem. The readings recorded at Heritage College were also within normal limits but were, on average, slightly lower than readings measured near Hanford.

Monthly average exposure rates ranged from 7.2 μR/h at Heritage College in December to 9.4 μR/h at Edwin Markham in April (a suspect reading because of subsequent equipment problems). Average monthly readings at the stations near Hanford were consistently between 8.2 and 8.7 μR/h and readings at Heritage College ranged between 7.2 and 7.8 μR/h. These dose rates were consistent with dose rates measured by the thermoluminescent dosimeters at these locations (Table 4.7.5).

Table 4.7.5. Quarterly Exposure Rates Measured by Thermoluminescent Dosimeters at Four Offsite Locations

	Exposure Rate, μR/h[(a)]			
Sampling Locations[(b)]	Leslie Groves Park	Basin City	Edwin Markham	Heritage College
Quarter Ending				
March	9.2 ± 0.04	8.7 ± 0.00	9.1 ± 0.46	8.5 ± 0.13
June	9.0 ± 0.33	9.0 ± 0.71	8.8 ± 0.04	8.2 ± 0.21
September	9.0 ± 0.13	8.9 ± 0.08	8.3 ± 0.21	8.2 ± 0.46
December	8.9 ± 0.08	8.7 ± 0.04	8.5 ± 0.17	7.8 ± 0.08

(a) ±2 standard deviations of the exposure rate.
(b) Sampling locations are illustrated in Figure 4.1.1.